# Project Plan

Mission and Science Measurement Technology (MSM) Theme

NASA Computing, Information, and Communications Technology (CICT) Program

# Information Technology Strategic Research (ITSR) Project

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| CICT Approved: | Eugene L. Tu, CICT Program Manager | Date |
| ARC Confirms: | G. Scott Hubbard, ARC Director | Date |
| ITSR Submitted: | David Alfano, ITSR Project Manager | Date |

# Information Technology Strategic Research (ITSR) Project

# 1.0 PURPOSE

## 1.1 Introduction

This document is the Project Plan for the NASA Computing, Information, and Communications Technology (CICT) Program's Information Technology Strategic Research (ITSR) Project. The Project described in this document will provide high-leverage, crosscutting technology solutions for the goals and objectives of its counterpart CICT projects as well as other Enterprise Programs and NASA Missions. In addition to providing a technology incubator, ITSR aims to support emerging needs in advance of specific system requirements.

The ITSR Project Plan provides an authoritative, top-level technical and management description of the project and is the controlling document for project content and organization. This project plan establishes:

- Project requirements
- Project objectives and performance goals
- Management organization responsible for the project throughout its life cycle
- Project resources, schedules, and controls

This project plan is consistent with NPD 7120.4, NPG 7120.5B, and ISO 9001. This project plan covers the time period of FY2002-2006 and is updated at least annually.

## 1.2 Project Goal

The goal of the ITSR Project is to:

**Research, develop, and evaluate a broad portfolio of fundamental information, biologically-inspired and nanoscale technologies for infusion into NASA missions.**

Many of the missions in NASA's future will rely on technologies that are new and dramatically different from those in current practice today. The challenges of deep space exploration, hostile environments, and remote science create a need for new materials; smaller, lighter, and less power consuming devices; highly reliable software; and reconfigurable computing and information technologies. ITSR provides a vehicle to identify the technologies that may be employed to accomplish NASA's missions of the future, and to explore them as possible solutions to the challenges provided by increasingly complex mission requirements.

ITSR provides a technology incubator where high-risk, high-payoff, and long-range technologies are identified, explored, developed, verified, and transferred to other parts of the CICT Program, as well as other Office of Aerospace Technology programs. This is a project where a number of related and unrelated technologies can be explored simultaneously, and evaluated for suitability for further development either as spin-off projects or as technologies that may be transferred to other research areas within the Enterprise.

The ITSR Project will be conducted in cooperation with other programs, the U.S. aerospace industry, the Department of Defense, the Federal Aviation Administration, and the academic community.

# 2.0 OVERVIEW

## 2.1 Background

ITSR is one of four projects of the CICT Program:

- Intelligent Systems (IS) Project
- Computing, Networks, and Information Systems (CNIS) Project
- Space Communications (SC) Project
- Information Technology Strategic Research (ITSR) Project

The goal of the CICT Program is to enable NASA's scientific research, space exploration, and aerospace technology missions with greater mission assurance, for less cost, and with increased science return through the development and use of advanced computing, information and communications technologies. The objectives for accomplishing this goal are the following:

1) Goal-Directed Systems: Enable smarter, more adaptive systems and tools that work collaboratively with humans in a goal-directed manner to achieve NASA's twenty first century mission/science goals.
2) Seamless access to NASA information technology resources: Enable seamless access to ground-, air-, and space-based distributed hardware, software, and information resources to enable NASA missions in aerospace, Earth science, and space science.
3) High rate data delivery: Enable broad, continuous presence and coverage for high rate data delivery from ground-, air-, and space-based assets directly to the users.
4) Strategic Research: Research, develop, and evaluate a broad portfolio of fundamental information and bio-nano-technologies for infusion into future NASA missions.

## 2.2 Technology Portfolio

The ITSR Project reviews the requirements of the next generation of NASA missions, then identifies technologies that can provide an implementation strategy for accomplishing those missions. These include missions in aeronautics and space transportation, space science and exploration, astrobiology, and Earth science. Key technologies are then explored until an appropriate level of development is reached whereby a technology's suitability for further development can be determined, different research directions can be taken, and transfer/spin-off, or replacement in the ITSR portfolio can be accomplished. It is anticipated that this dynamic structure will allow ITSR to explore new and revolutionary technologies in a context unique to NASA and its capabilities and challenges.

Periodically, technologies in the ITSR Project will be evaluated for their technical quality as well as their continued relevance to NASA missions. Following evaluation, decisions will be made regarding how best to exploit the technology within the CICT Program, and more mature technologies will be transferred to other areas ( e.g. other Projects, Programs, and through technology transfer). New technologies may then be evaluated to take their place in the portfolio.

ITSR is a multi-center activity managed by the CICT ITSR Project Office at Ames Research Center. In addition to in-house NASA research, ITSR takes advantage of a high technology University Research Engineering and Technology Institute (URETI) in nanoelectronics and computing, as well as research funded through NASA Research Announcement (NRA) grants. This unique arrangement of small, high-risk, high-payoff technologies and a mix of in-house, university and industry partnership will provide technologies that can be applied to NASA missions throughout the 21st century. The ITSR Project specifically addresses CICT objective (4) above.

# 3.0 DETAILED PROJECT OBJECTIVES

The ITSR Project focuses on accomplishing the following objectives:

- Prototype breakthrough technologies, on a continuing basis, and evaluate their suitability for application to NASA missions.
- Demonstrate new and emerging technologies suitable for transfer or spin-off.
- Transfer technologies to other portions of the CICT Program, or other Enterprise programs and their Missions.

The ITSR Project operates with these objectives in order to identify, develop, prototype, and supply advanced and revolutionary technologies to a number of entities within NASA. When activities reach an appropriate level of maturity, ITSR will provide these new technologies to other projects within CICT (including new projects, as appropriate), other Programs within the Aerospace Technology Enterprise, and other NASA Enterprises.

# 4.0 PROJECT MANAGEMENT OVERVIEW

## 4.1 Authority

The NASA Headquarters Program Management Council (PMC) establishes the overall program authority. The CICT Program Commitment Agreement (PCA) is the Agency-Level agreement for implementation of the CICT Program. The CICT Program Plan documents program implementation and the commitment between the Director, Mission and Science Measurement (MSM) Technology Theme, and the Associate Administrator for Aerospace technology. The ITSR authority is derived from the CICT Program Commitment Agreement and the Program Plan.

## 4.2 Organization

The overall CICT Program management organization is shown in Figure 4-1. The Theme Director, Mission and Science Measurement Technology, at NASA Headquarters is responsible for the overall CICT program strategy, policy, direction, control and evaluation. The Theme Director assigns management control, formulation and implementation responsibility for the program to the CICT Program Manager.

The CICT Program Office manages the CICT Program. Offices at Ames Research Center manage three CICT projects, IS, CNIS and ITSR, and a Project Office at Glenn Research Center manages the SC Project. Project implementation responsibility for ITSR resides at Ames, Glenn, and Langley Research Centers, Dryden Flight Research Center, Marshall Space Flight Center, and the Jet Propulsion Laboratory (JPL).

ARC is the NASA lead center for the management and implementation of the ITSR Project in the CICT Program.

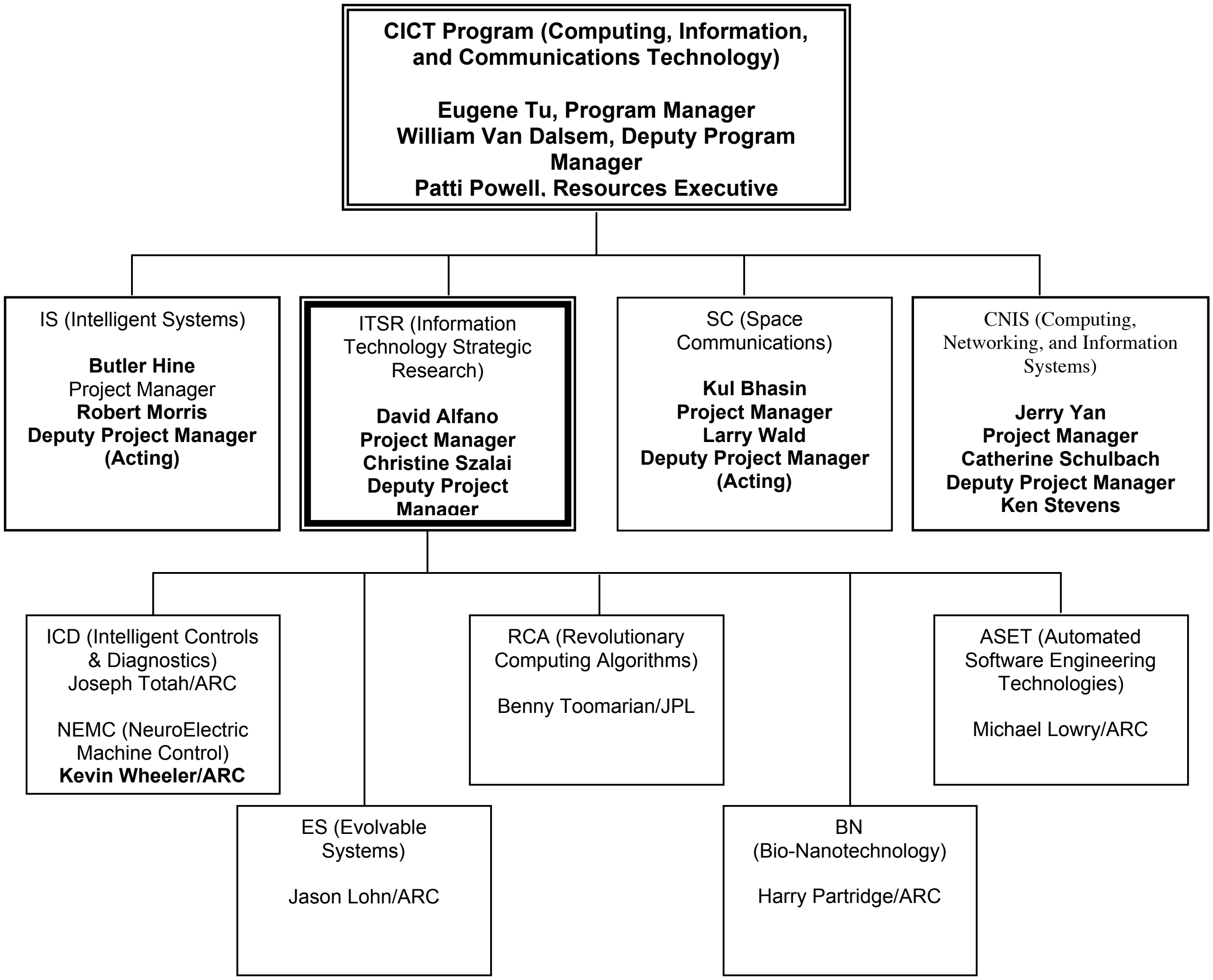


**Figure 4-1 ITSR Organization Chart**

## 4.3 Responsibilities

### 4.3.1 ITSR Project Management

Responsibilities of the ITSR Project and Deputy Managers include the following:

- Supporting CICT Program Management.
- Overall management of the assigned multi-center project, including cost, schedule, and technical performance.
- Preparing and maintaining the project plan, schedules, and budgets.
- Forming the project team and executing the project plan.
- Establishing and approving support agreements.

- Providing appropriate attention to financial and acquisition management, risk management, performance management, and safety and mission assurance.
- Reporting project performance and status to the CICT Program Office and as otherwise required.
- Submitting project reports and preparing and presenting project reviews and technical advocacy materials.
- Supporting CICT Program management and integration.
- Managing a peer review process for relevance to NASA interests and overseeing sub-project peer review processes for technical quality.
- Managing relationships with customers and potential customers.
- Maintaining a current Project-level website linked to the CICT Program website.
- Complying with applicable Federal law, regulations, Executive Orders, and Agency Directives.

### 4.3.2 ITSR Sub-Project Management

Sub-Project Managers lead and coordinate the performance of work in a Work Breakdown Structure (WBS) element. Sub-Project Managers work with other WBS Sub-Project Managers at their centers. They also work with other WBS Sub-Project Managers within the same technology element. The responsibilities of the Sub-Project Manager include:

- Supporting ITSR Project Management.
- Representing a WBS element to the ITSR Project and Deputy Project Manager.
- Leading the definition of resources, schedules, deliverables, and commitments in a WBS element.
- Managing technical efforts in a WBS area.
- Managing a WBS budget.
- Reporting technical performance and status to the ITSR Project Manager and Deputy, other Project personnel, and line managers.
- Managing a technical peer review process.
- Generating and maintaining agreements with Performing Organizations for activities in the Sub-Project.

## 4.4 Reviews

Efficient management of ITSR requires effective communication through reviews and reports to the CICT Program Office, management, working groups, and industry. Below are reviews that have been established to communicate progress and information at the program and project level. Sub-Project reviews are covered in individual Sub-Project Plans.

- ITSR Relevance Review: The ITSR project will host an annual review for relevance by Enterprise and other customer representatives.
- ITSR Peer Review: The ITSR project will require annual technical peer reviews of all sub-projects and the tasks comprising them.
- CICT Program Reviews: The ITSR project reports technical, cost and schedule status on a quarterly basis to CICT Program Management. An in-depth review of the ITSR Project will be conducted annually by CICT Program Management.

- Enterprise Reviews: ITSR will support and participate in formal reviews of the CICT program as required by OAT or any of the other Enterprises. Scheduled follow-ups to FY02/03 reviews by the National Research Council (NRC) and the Aerospace Technology Advisory Committee (ATAC) are planned.
- Center Reviews: ITSR participates in the monthly ARC Program Management Council (APMC) review in addition to any other reviews as required by NASA Ames center management.
- Other Reviews: The ITSR project also supports other reviews as required.

## 4.5 Reporting

Requirements for effective reporting will be met, at a minimum, as follows:

- Weekly oral status reports from ITSR Project Management to CICT Program Management.
- Monthly written ITSR status reports to CICT Program Management and the ARC Programs Management Council (APMC).
- Quarterly written ITSR status reports to CICT Program Management for submittal to the Associate Administrator to include: program milestones accomplished and any other significant technical progress during the previous quarter; status against metrics to document progress and relate technical performance to cost and schedule; planned events for the upcoming quarter; resource and schedule variances; changes to the plan; and major issues.
- Monthly ITSR Financial and Contractual Status reports documenting commitment, obligation and cost.
- Monthly and quarterly updating of ITSR financial and technical status in NASA's Erasmus database.
- Update of ITSR GPRA milestone status in NASA's PMAS database.
- Weekly highlight submission to the CICT Program Office as well as Center Line Management.
- Annual update of ITSR information in the Technology Inventory Database (TIDB) and the Program Managers' Accomplishment System (PMAS) database.

## 4.6 Technology Selection and De-selection

ITSR's charter is to research, develop and evaluate a broad portfolio of fundamental information and bio-nanotechnology for infusion into NASA missions. These technology areas, often cross-cutting in nature, are intended to identify suitable technology implementation paths for NASA's technology requirements across all of the Enterprises. ITSR explores new and emerging technologies in the context of long-horizon NASA mission requirements and scenarios, and evaluates these technologies for suitability for development and implementation to achieve Enterprise goals.

### 4.6.1 Requirements Capture

The NASA Office of Aerospace Technology, Office of Earth Science, Office of Space Science, Office of Biological and Physical Research, Office of Human Exploration & the Development of

Space, and Office of Human Resources and Education are the intended beneficiaries of ITSR as are the other projects within the CICT Program. Overall project objectives, requirements, and metrics are established by consensus between sub-project leads, ITSR project management, and CICT program management.

A portion of the initial ITSR portfolio was derived in part from the Information Technology Base Program (IT Base), and portions of the Intelligent Systems Program (IS). Given the overall reduction in financial resources available, the highest priority efforts from IT Base and IS, which fit the charter of ITSR, were retained. A substantial effort in Bio-Nanotechnology is also a significant part of the Project.

The ITSR portfolio is based upon NASA's Enterprise objectives and missions, as well as long-term science requirements for which the technology implementation is currently uncertain. For Enterprise requirements data, the ITSR project relies on the Mission and Science Measurement Technology (MSM) and CICT systems analysis activities, as well as input from the CICT Program Office and Enterprise Liaisons. The requirements gathering phase of these joint systems analysis activities began providing data to CICT Projects in FY03. As this activity becomes more formalized and established, it will become an integral part of the Program and Project annual planning cycles.

### 4.6.2 Selection Criteria

ITSR focuses on high-risk, high-payoff technologies for long-horizon application. However, new opportunities for investment areas are considered annually, and as resources allow. Sources for new opportunities may come from diverse sources such as the MSM/CICT systems analysis, the CICT Program Office, mission requirements input from the Enterprise Technology Executive Board (TEB), annual sub-project peer reviews, direct requests from mission planners across NASA Enterprises, recommendations from technical advisory committees, and competitive sourcing (NASA Research Announcements, and Broad Agency Announcements).

ITSR management collects data and evaluates priorities for research from a variety of sources including and the CICT Program Office, the National Research Council Review, Agency and Enterprise Strategic Plans, periodic Program-wide review of relevance by Enterprise representatives, ITSR technical peer reviews, the Systems Analysis output, and direct mission planner interfacing.

### 4.6.3 Technology Maturation and Transfer

Currently, ITSR's portfolio includes research and development in high-confidence software verification and synthesis; evolvable systems for survivability/function; neural-based control of vehicles and systems; sensor fusion and data fusion; new human/machine interface modalities; bio-inspired and nanoscale computing and electronics; and algorithms for biology-based and physics-based computing. Most ITSR work involves low Technology Readiness Level (TRL) levels. Customer partnership and a technology transfer plan are in place by mid-term of development activities. There is no funding beyond TRL 6.

Success with infusing technology into NASA missions depends on targeting initial mission applications early in the development process and working jointly with Enterprise mission staff towards technology infusion. While the Agency has no formal infusion program, the Program and Projects work tactically with Enterprise staff having authority to make these decisions. Enterprises infuse technologies in different fashions (e.g. early planning, dedicated technology pathfinder missions, etc.), and this is taken into consideration during interaction with the Enterprises and their missions.

It is anticipated that in FY04, increased opportunities for technology infusion will result from CICT Enterprise Liaisons appointed in FY03, and from a new annual relevance review by Enterprise representatives. Both of these activities provide greater visibility of ITSR work among Enterprise representatives along with increased opportunity for collaboration and planning.

Examples of current collaborations include:

As ITSR's Automated Software Engineering Technologies (ASET) Sub-Project work moves to TRL 4 or 5, ASET hands off technologies to the Engineering for Complex Systems (ECS) Program, which has a high-dependability computing program. ECS is a mid- or higher-TRL recipient of ASET technology. ASET also produces work that is applicable to autonomous systems in the IS Project, and anticipates spin-off to the Mars Technology Program as early as FY04.

The ECS program's Resilient Systems and Operations work is comprised in part of technologies developed in ITSR’s Intelligent Diagnostics and Controls (ICD) Sub-Project.

The Evolved Antenna Synthesis activity in ITSR's Evolvable Systems (ES) Sub-Project is currently working with the New Millennium Program to field an evolved antenna on the ST-5 space mission as proof of concept of Evolvable Antenna Synthesis technology.

# 5.0 TECHNICAL COMMITMENT

This section details ITSR Project level milestones, shows a Work Breakdown Structure for organizing the work and accomplishing the milestones, and provides an overview of ITSR sub-projects. Sub-project level milestones and more detail on sub-projects can be found in individual sub-project plans.

In the CICT Program Commitment Authority (PCA) document, ITSR was assigned PCA milestone #8.0. ITSR Project level milestones, supporting PCA 8, are listed in this section. ITSR Sub-Project level milestones are listed in each Sub-Project plan.

## 5.1 Milestones

This section shows Project milestones and metrics directly supporting the accomplishment of PCA 8.

| MILESTONES | DUE DATE | METRICS |
|---|---|---|
| 8.0 New technology demonstration and transfer.<br><br>Demonstrate application of bio-nanotechnology in a context relevant to NASA missions.<br><br>Demonstrate new technologies that enhance system reliability, adaptability, capability, or robust operation. | Sep-06 | Evaluate and promote at least 5 new bio, nano, or information technologies impacting at least 2 NASA Enterprises to a status appropriate for transfer to another NASA program or project, or insertion into a NASA mission. The current research portfolio includes nano-scale component development and assembly; intelligent, adaptive, immersive, multi-modal control of aerospace vehicles; high confidence automated software development and verification; adaptive and fault-tolerant systems; and new models of computing for emerging and anticipated platforms. |
| 8.1 Design, fabricate and evaluate carbon nanotube electronic devices. | Sep-02 | A reliable and reproducible technique to grow a carbon nanotube based inverter logic circuit. A critical step in enabling electronic devices with nano-scale components for OSS and OBPR applications. |

| MILESTONES | DUE DATE | METRICS |
|---|---|---|
| 8.2 Develop program synthesis technology that enables product-oriented certification, rather than certification for flight based on traditional methods. | Sep-03 | A program synthesis engine for an aerospace domain that produces highly annotated code, assuring adherence to safety and effectiveness properties. Demonstration of the product-oriented methods for certification is principally on state estimation code (e.g., attitude state estimation) and data analysis code. A new approach to certification of mission-critical code, enabled through program synthesis, which will be semi-automatic for certain classes of properties. |
| 8.3 Demonstration of fault recovery from multiple faults for a digital controller via direct, on-the-chip hardware evolution. | Sep-03 | Ability to recover functionality from up to 3 injected latch-up faults, with sub-second fault recovery time. Increased reliability of digital control systems deployed in extreme environments by using direct, on-the-chip hardware evolution. |
| 8.4 Demonstrate a simplified adaptive flight control system that exhibits equivalent or improved levels of safety and handling qualities following damage. | Sep-05 | Flight test results demonstrating a simplified adaptive flight control system provides equivalent or improved levels of safety and handling qualities following damage without the requirement for on-line parameter identification and/or other computationally expensive components. An adaptive flight control technique that is less complex, easier to implement, and can be retrofitted to existing flight control laws in modern aircraft. |
| 8.5 Demonstrate the development of prototype nanotechnology sensor for biological or environmental monitoring. | Sep-05 | Demonstrate development of prototype chemical or biosensor demonstrating high sensitivity and selectivity with low mass and power requirements. Demonstrates ability to develop nanotechnology sensors for NASA applications. |

| MILESTONES | DUE DATE | METRICS |
|---|---|---|
| 8.6 Demonstration of propulsion health management technologies for engine performance enhancement and component health and safety monitoring. | Sep-06 | (1) An adaptive control system for turbine casing cooling flow to accommodate the effect of engine degradation on turbine clearance. Maintain design efficiency of the turbine as the engine degrades by maintaining the clearances to the design level, resulting in increased engine life due to reduction in rate of exhaust gas temperature degradation and consistent performance over the engine life.<br>(2) Development of HealthWatch III (HW-3) including a programmable data acquisition system and the ability to sample and store high-speed data in operation. A health monitoring system for integrated real-time sampling of both vibration and oil-debris signals for advanced damage detection of incipient component degradation. |
| 8.7 Demonstrate reliable, repeatable fabrication procedure for nanoelectronic components that do not require manual manipulation in assembly. | Sep-06 | Demonstrate development of fabrication and integration approach for nanoelectronic components. Demonstrates manufacturability of nanoelectronic systems for use in NASA applications. |
| 8.8 Integrated verification and monitoring technology. | Mar-06 | Demonstrate integrated verification and monitoring technology that can detect and recover from errors during software execution. Methods for safe execution of software that have modest impact on performance. |
| 8.9 Domain-specific program synthesis tools. | Sep-06 | Demonstrate technology enabling domain experts to customize and extend high-assurance program synthesis tools. 2x reduction in cost for extending high-assurance program synthesis tools. |
| 8.10 Develop novel, nanotechnology-based sensors for in situ and remote sensing. | Sep-06 | 1) Development of 4 new chemical, biological, or physical sensor technologies and the enabling nanotechnology materials, structures and electronic devices for these novel sensors for NASA applications. 2) Demonstrate feasibility of a solid-state nanopore-based device that can identify variation in conductive organic polymers including human DNA. Demonstrate ability to exploit developments in the nanoscale sciences to develop instrument prototypes to accomplish OSS and OBPR strategic objectives. |

| MILESTONES | DUE DATE | METRICS |
|---|---|---|
| 8.11 Demonstrate an intelligent maneuvering system capable of incorporating planning and decision-making models to give the vehicle goal directed self-reliant behavior with a high degree of autonomy. | Sep-06 | 1) An intelligent maneuvering system that incorporates long-term planning to meet mission objectives, within mission constraints and performance limitations, while incorporating vehicle performance assessments and accommodating other unforeseen circumstances. 2) A system capable of performing time-critical flight path operations, which includes aggressive maneuvers in the presence of unexpected obstacles, by selecting discrete flight modes and targets in order to achieve strategic maneuvering objectives. The development of an intelligent maneuvering system capable of carrying out defined flight-path goals for a wide range of piloted and uninhabited vehicle classes, including fixed-wing, rotorcraft, and reusable launch vehicles. Success criteria will be the ability of the system to achieve equivalent pilot performance. |
| 8.12 Demonstration of novel computational methods for neuro-electric machine control capabilities using EMG and EEG signals for closed-loop control, and human augmentation. | Sep-06 | Demonstrations of neuro-electric machine control capabilities including: a) using EMG to control a graphical simulation in a closed-loop simulation, b) using EEG for augmenting human cognitive performance, c) report of novel biological and physics inspired pattern recognition technology. Feasibility determinations of the strengths of bioelectric signals that can be used for device control and human performance augmentation for use in Aeronautics, space-based or commercial applications. Success metrics will be the ability of the technology to operate in near-real time tasks such as database queries and complex monitoring or control tasks. Performance tests of the new pattern recognition algorithms. |
| 8.13 Explore, design, and characterize novel devices, architectures, and algorithms to demonstrate evolutionary and adaptive behavior in nanoelectronics for switching, logic, communications, and sensing functions. | Sep-06 | 1) Computational models and laboratory devices demonstrating the ability to control design specifications and performance of nanoelectronic devices. 2) Develop software algorithms that can generate nanoelectronic architectures containing memory, logic, and/or sensors that perform desired digital or analog functions in the presence of manufacturing defects (e.g. Space Science missions). |

| MILESTONES | DUE DATE | METRICS |
|---|---|---|
| 8.14 Formally verify the software infrastructure for integrated modular avionics. | Jun-05 | Demonstrate tools and methods capable of analytically verifying time partitioning in a flight-ready OS for avionics. Reduce cost of avionics upgrades in airline fleet by 25%. |
| 8.15 Develop tool that can automatically generate test scenarios from unit up through system-level from a design specification expressed in a commercial modeling notation. | Sep-06 | Demonstration of tool that generates at least 75% of needed test scenarios for suitable coverage criteria (including MC/DC) up to system level. 50% reduction in manual effort to develop test scenarios for certification. |
| 8.16 Demonstrate self-aligned hierarchical nano electronic and sensor systems. | Sep-06 | Development and demonstration of hierarchical nanodevice for electronic and sensing application based on nanowire, molecular wire, and/or resonant tunneling diode technology. Demonstrated building blocks and fabrication techniques for nanoscale electronic devices and sensors. |
| 8.17 Demonstrate automated design algorithm capability in support of a NASA Mission. | Sep-04 | Evolvable Antenna Synthesis generates an antenna design suitable for the requirements of the NASA ST-5 mission. Evolved antenna design process is 15% shorter than conventional (current) design processes. |

## 5.2 Work Breakdown Structure

To accomplish its goals and objectives, the ITSR Project is organized into six sub-projects: Evolvable Systems (ES), Automated Software Engineering Technologies (ASET), Intelligent Controls and Diagnostics (ICD), NeuroElectric Machine Control (NeMC), Revolutionary Computing Algorithms (RCA), and Bio-Nanotechnology (BN). The ICD sub-project will sunset in FY05, and pertinent technologies are being carried forward in the expanding NeMC work that is projected to execute through FY06. Previously, NeMC technologies, in their infancy, were hosted in the ICD sub-project.

The ITSR Work Breakdown Structure is shown in Figure 5-1.

| | Title | POC |
|---|---|---|
| Project Level | | |
| | *Evolvable Systems (ES)* | Lohn, Jason |
| | *Automated Software Engineering Technologies (ASET)* | Lowry, Mike |
| | *Intelligent Controls and Diagnostics (ICD)* | Totah, Joe |
| | *NeuroElectric Machine Control (NeMC)* | Wheeler, Kevin |
| | *Revolutionary Computing Algorithms (RCA)* | Toomarian, Benny |
| | *Bio-Nanotechnology (BN)* | Partridge, Harry |
| Evolvable Systems (ES) | | |
| | *Dynamic Evolution for Fault Tolerance* | |
| | *Evolutionary Algorithms for Scheduling* | |
| | *Automated Design of Spacecraft Antennas* | |
| | *Evolvable Hardware for Sensors* | |
| Automated Software Engineering Technologies (ASET) | | |
| | *University Research in Dependable Computing* | |
| | *Formal Methods: Requirements/Design Analysis* | |
| | *High Assurance Software Design* | |
| | *Program Synthesis* | |
| Intelligent Controls and Diagnostics (ICD) | | |
| | *Intelligent Health and Safety Monitoring* | |
| | *Intelligent Controls and Diagnostics for Propulsion Systems* | |
| | *Intelligent Flight Control* | |
| | *Intelligent Automation* | |
| NeuroElectric Machine Control (NeMC) | | |
| | *Neuroelectric Machine Control* | |
| Revolutionary Computing Algorithms (RCA) | | |
| | *Quantum Computing* | |
| | *Biology inspired Computing* | |
| | *Molecular Computing* | |
| Bio-Nanotechnology (BN) | | |
| | *Nanomaterials for Electronics and Sensors* | |
| | *Modeling and Analysis of Nanotechnology* | |
| | *Manufacturing at the Nanoscale* | |
| | *Nanoelectronics* | |
| | *Bio-Nano-Based Diagnostic Tools* | |
| | *Nano-based Sensors and Instruments* | |
| | *Nanocomputing* | |

**Figure 5-1 ITSR Work Breakdown Structure**

## 5.3 Evolvable Systems (ES)

The primary goal of this task is to dramatically increase mission survivability and science return through development and application of evolutionary and adaptive systems. To reach this goal, ES will research and develop advanced evolutionary and adaptive algorithms in three main focus areas: reconfiguration and re-use, optimization and design, and adaptation and learning.

Future NASA missions will require both hardware and software systems that can respond to and recover from component faults and failures. Evolvable Systems are hardware and software systems that can adapt, self-improve, self-repair, and self-reconfigure. Biology provides several examples for the design and control of evolvable systems: evolution, immune systems, and metabolic networks. The benefits of Evolvable Systems technology include robustness in the event of component failures, graceful degradation of function in the event of large numbers of component failures, tolerance to changing environment by adaptation, and the potential to generate new functionality.

Evolvable Systems is subdivided into three areas. Reconfiguration and re-use is an area where systems reconfigure or re-use available resources for new or existing functions. Optimization and design is concerned with improving existing systems and creating new systems designs using techniques such as evolutionary algorithms. Adaptation and learning systems adapt to new environments by sensing, learning, and automated discovery.

### 5.3.1 Reconfiguration and Reuse

Reconfiguration and re-use efforts will focus on systems reconfiguring or re-using available resources, typically on the fly, for new or existing functions. For example, if, during transit, an avionics logic subsystem fails, a field-programmable gate array chip has the potential to be "re-wired" dynamically to provide the missing hardware functionality. Other applications include dynamic reconfiguration for high radiation and high temperature environments. On-chip evolution using field-programmable transistor and gate arrays has shown encouraging initial results in these application areas.Reconfiguration and re-use efforts will focus on systems reconfiguring or re-using available resources, typically on the fly, for new or existing functions. For example, if, during transit, an avionics logic subsystem fails, a field-programmable gate array chip has the potential to be "re-wired," on-the-fly, to provide the missing hardware functionality. Other applications include dynamic reconfiguration for high radiation and high temperature environments. On-chip evolution using field-programmable transistor and gate arrays has shown encouraging initial results in these application areas.

### 5.3.2 Optimization and Design

Optimization and design efforts will focus on improving existing systems and creating new systems designs using techniques such as optimization of spacecraft antenna whereby both electrical and mechanical properties are simultaneously optimized under the control of an evolutionary algorithm. The Automated Design of Spacecraft Antennas activity is currently working with the New Millennium Program to field an evolved antenna on the Space Technology-5 (ST-5) mission. Another application area is nanoelectronic design: as nanotechnologists make advances in device design, it becomes imperative that architectures be developed to effectively utilize the new devices, given the yields of construction and self-assembly techniques likely to be applied. Evolutionary algorithms have proven themselves as a technology capable of combing large design spaces (e.g., analog electronics). As such, applying evolutionary algorithms to search out effective nanoelectronic architectures is a natural application.

### 5.3.3 Adaptation and Learning

Adaptation and learning efforts will focus on systems that can adapt to new environments by sensing, learning, and automated discovery via advanced biologically inspired algorithms. Work in this area is primarily focused on robotic applications since adaptation and learning in robotic systems is critical for achieving autonomy. An example application is a modular robotic system comprised of identical components. The key challenge is how one programs each of the modules to cooperate with the neighboring modules. This problem is a distributed control problem and one where evolutionary algorithm technology has had initial success in small-scale applications. Another application area is in evolutionary scheduling systems. The goal is to use advanced algorithms to produce effective schedules and to adapt schedules dynamically as required by the addition of new requirements or science data. For example, the imaging devices flying on a fleet of satellites would need to be repeatedly re-scheduled as it is determined where the interesting regions are located.

## 5.4 Automated Software Engineering Technologies (ASET)

NASA's reliability and confidence in its software systems for mission and safety critical applications has been identified as the priority technology challenge in at least one Enterprise (Code S), and is a high priority for many others. ASET's objective is to develop technologies and tools to significantly enhance the safety and security of aerospace software systems, reduce software development time and cost, and enable next-generation avionics. ASET's goal is to develop the automated tool support to make a mathematically based engineering discipline for high confidence software cost-effective.

As the complexity of modern missions increases in response to science data requirements, more of this complexity is being assigned to software for implementation. However, current software development and verification technologies do not adequately provide the high level of confidence in software that is desired and implied. Code R, and MSM in particular, has a commitment to address this critical gap with revolutionary technology development. It is known that part of the solution needs to be process improvements, and several initiatives within NASA are addressing this issue. But there is an underlying technology gap that management process changes alone cannot address - the lack of a mathematical basis for an engineering discipline for aerospace software development, in contrast to other engineering disciplines for aerospace. This task not only addresses this critical gap, but also develops technology to provide the automated tool support to make a mathematics-based engineering discipline for high-confidence software cost-effective.

ASET research includes formal methods for requirements and design specification, automated code generation, high-assurance design techniques, and appropriate verification and validation methods for these exciting new technologies. ASET aims for a total systems approach to its objectives. ASET is organized around four main areas, as follows.

### 5.4.1 University Research in Dependable Computing

NSF and NASA will cooperate to fund projects that will promote the ability to design, test, implement, evolve, and certify highly dependable software-based systems. A significant feature of this solicitation is the use of a new NASA testbed facility that will allow researchers to experimentally evaluate their research products on significant real hardware/software artifacts.

The overall goal of this solicitation is to develop a scientific basis for measurable and predictable dependability in software-based computing and communication systems, and a scientific basis - comparable to those in physics-based engineering disciplines - for technologies or methodologies to improve dependability in these systems. If this is successful, then it is anticipated that government agencies as well as U.S. industry will have a scientific basis for dependably using software-based systems, and for using technology interventions to achieve a predictable level of dependability. The key to this scientific feasibility is clearly defined attributes that can be objectively measured. Dependability attributes should encompass both aspects relevant to the dependability of deployed computing systems, and attributes that can be measured before deployment - such as the complexity of interfaces between subsystems, or the results of necessarily limited testing prior to deployment.

### 5.4.2 Formal Methods for Requirements/Design Analysis

The Formal Methods task is investigating the use of mathematical specification and verification of software requirements and design, as a means of increasing the reliability of digital avionics systems. This element focuses on the requirements/design stages of aerospace software development. This is a departure from the more traditional software development methodologies, which rely on careful process management of the software development life-cycle to provide reliability. While the main focus is on the application of verification theorem proving to aerospace requirements/design, this element also identifies gaps in the underlying theorem proving technology and funds needed improvements in the technology.

### 5.4.3 High-Assurance Software Design

The High-Assurance Software Design task is investigating and developing tools to increase the integrity and reliability of software for safety-critical and mission-critical flight applications. The emphasis is on scaling-up and automating analytical methods for verification and debugging across the software life-cycle. This effort extends the application of formal methods into later areas of the software development life-cycle, to include design and implementation.

### 5.4.4 Program Synthesis

Program synthesis, through automated logical reasoning, has the potential to address reliability, cost, and schedule. The Program Synthesis task is investigating efficient algorithms for automated high-assurance generation of software designs and code, from requirements and specifications. This is a two-track effort. One track is to enhance the integrity of current commercial avionics code generators, which are based on traditional compiler technology. The second track is to scale up new code-generation methods being developed in the research community that are intrinsically high-assurance, but not necessarily computationally efficient. A secondary objective is to develop technology for safely and efficiently reusing software (including design, architecture, and code), thus leading to avionics product families.

## 5.5 Intelligent Controls and Diagnostics (ICD) and NeuroElectric Machine Control (NeMC)

Intelligent Controls and Diagnostics (ICD) and NeuroElectric Machine Control (NeMC) are sub-projects under ITSR. The ICD sub-project will sunset in FY05, and pertinent technologies are being carried forward in the expanding NeMC work that is projected to execute through FY06. Previously ,NeMC technologies, in their infancy, were hosted in the ICD sub-project. Beginning in FY04, NeMC is defined in this plan document as a separate sub-project, closely associated with ICD.

The objectives of NeMC are to improve integrated human/system performance, as well as reduce development time and operational cost. The approach in ICD is to develop adaptive flight control systems that automatically compensate for failures or damage that would otherwise result in a catastrophic event, develop predictive component/subsystem diagnostic methods to detect and isolate imminent component malfunctions well in advance of a failure, and develop outer-loop technologies to intelligently maneuver a vehicle under nominal and off-nominal conditions. The approach in NeMC builds upon the system-level approach in ICD by developing machine learning algorithms to tighten the control loop and provide a new computer interfacing modality in immersed human machine systems.

Many of the technologies in ICD are developed for aircraft, launch vehicles, and spacecraft applications (piloted, remotely operated, and autonomous). The technologies in NeMC will have broader applications to in-space construction and the associated interaction with robotic devices. The intent is to leverage information technologies and core competencies in soft computing and computational intelligence to support specific objectives within NASA's Strategic Plan. The value added to NASA's missions resulting from an investment in these sub-projects are to improve safety, reduce cost (during design/development and operation), increase efficiency, and extend operational life for flight critical components, subsystems, overall vehicle, and fully integrated human/machine systems. The following tasks comprise the work breakdown structure for both sub-projects.

### 5.5.1 Intelligent Health and Safety Monitoring (IHASM)

The objective of this task is to develop efficient and effective information processing software, of a generic nature, to be used in next generation aerospace vehicles to detect, isolate, or rectify imminent or foreseeable component malfunctions. The scope of this element will encompass six broad research goals:

- Establish the combined effects of design, manufacturing, installation, flight operations, and fatigue damage on observable vibrations.
- Experimentally determine nominal statistical signatures of rotating elements under dynamic operating conditions.
- Develop first-principles modeling techniques to produce canonical reference signatures for fault propagation.
- Develop effective real-time statistical algorithms for damage detection (i.e., high hit rates and low false-alarm rates) under dynamic, non-stationary, operating conditions.

- Develop synthetic fault data populations, using Monte Carlo techniques, for evaluation of real-time anomaly detection and fault classification algorithms.
- Develop an integrated database architecture to facilitate broad scientific and industrial access to the growing body of U.S. Government vibration data generated during the program. This will incorporate data from Ames, Glenn, and Dryden.

### 5.5.2 Intelligent Controls and Diagnostics for Propulsion Systems (ICDPS)

The objective of this task is to develop and validate advanced control system and health monitoring technologies that are critical to enhancing the safety, reliability and operability of aerospace propulsion systems. The ICDPS research effort will directly contribute to the NASA goal of enabling a safer, more secure, efficient, and environmentally friendly air transportation system. In addition, these new technologies can meet access to space objectives through application to air-breathing propulsion systems targeted for space access.

### 5.5.3 Intelligent Flight Control (IFC)

The objective of this task is to develop next generation neural flight controllers using enhanced neural network algorithms and adaptive control technologies. These controllers will be developed to exhibit higher levels of adaptability than current state-of-the-art systems, for the purpose of automatically compensating for a broader spectrum of damage or failures, controlling remote or autonomous vehicles, and reducing costs associated with flight control law development.

### 5.5.4 Intelligent Automation (IA)

The objective of this task is to develop comprehensive methods for achieving increasingly higher levels of automation for flight vehicles. Several core capabilities will be investigated in order to automate many of the actions currently performed by pilots. These actions include the internal management of a vehicle's health, assessment of the current operating environment, and the determination of action in the form of strategic planning and tactical maneuver selection. Automation interfaces will also be explored in order to address the human interaction at the goal-oriented management level.

### 5.5.5 NeuroElectric Machine Control (NeMC)

The objective of this sub-project is to provide the capability of communicating silently with a machine and with other people by using the natural interface of speech, but speech that is unspoken. The capabilities provided by this technology development exceed this application and will provide the means for general human/computer interfaces for other future brain computer applications. Simultaneous EMG/EEG silent speech could then allow for the use of both mind and body together in one interface. The multi-modal nature of this work will:

- Develop new modes of interaction that operate in parallel with existing modes such as typing and walking.
- Augment human-system interaction in wearable, virtual, and immersive systems by increasing bandwidth and quickening the interface.

- Enhance situational awareness by providing immediate and intimate connections between the human nervous system and the systems to be controlled or monitored.
- Develop silent speech recognition technology using EMG and EEG data signals.

## 5.6 Revolutionary Computing Algorithms (RCA)

Revolutionary Computing Algorithms (RCA) is a sub-project under ITSR. RCA efforts will focus on revolutionary models and algorithms for computation to enable future space-borne computing. In space, thermal and radiation effects introduce progressively larger error rates with decreasing semiconductor feature size. The physical difficulties associated with computing in space, combined with the number and complexity of applications needed in future missions, require new approaches to computing.

The focus of RCA is to develop alternative computing methodologies and models, suitable for the space environment, with the requisite high speed, low mass, and low power consumption necessary for future spacecraft. Candidate approaches to this NASA-unique requirement are new physics-inspired and biologically inspired approaches to computing. The success of this effort will be measured by the degree to which researchers are able to demonstrate the feasibility of these new approaches to solving strategic problems facing NASA.

The RCA work will pioneer radical new approaches to achieving higher-performance systems and seek breakthrough technologies to achieve orders-of-magnitude improvement in computing capabilities. While traditional measurements of capability, such as speed, memory, storage, and network bandwidth, continue to be important, the prospect of high-performance computer systems on-board flight and space vehicles elevates the importance of measures such as weight, size, durability, power consumption and thermal management. Miniaturization, device modeling, and architectural research are all components of the effort aimed at this objective. Realization of several orders-of-magnitude improvement in computing power and data storage requires exploration of novel devices and nanoelectronics. The goal here is to develop a highly integrated and intelligent simulation environment that facilitates the rapid development and validation of future generation nanoelectronics devices, as well as associated materials and processes through virtual prototyping at multiple levels of fidelity. Finally, revolutionary software capabilities, such as fault tolerance, transparent computing, legacy code translation, and universal programming models will support the overall objective as well.

The approach to RCA is to investigate scientifically inspired approaches to computing, described as follows.

### 5.6.1 Physics-Inspired Approaches to Computing

Quantum Computing is a revolutionary approach to computing in which quantum effects, such as superposition, interference, and non-determinism, are exploited in the service of a new approach to computation enabling efficient solutions to problems heretofore deemed intractable.

Quantum computers are envisioned to be able to perform certain computational tasks exponentially faster than any classical computer. Thus, if successful, this work will develop efficient algorithms to enable practical implementations of many critical NASA-related application domains, such as scheduling, planning, pattern recognition and data compression. Furthermore, revolutionary models of computation based upon a quantum physics approach will be a focus of this effort.

Although quantum computing is now in its infancy, success in this research area would have direct and revolutionary impact on NASA's missions of aeronautics and space exploration. Although there may be other advantages, such as size, the focus on quantum computing stems primarily from NASA's need to efficiently solve "intractable" computational problems that arise in a wide range of contexts. For example, future deep space missions will be largely conducted by sophisticated, autonomous spacecraft operating in harsh environments and under extreme constraints on permitted mass, time to respond, and available electrical power. These robotic explorers will need massive computational power to endow them with capabilities such as on-the-fly mission replanning, real-time onboard data analyses, and autonomous diagnosis, repair, and reconfiguration, to name but a few.

- The specific goal is to develop novel and efficient quantum based algorithms that address NASA relevant problems.

### 5.6.2 Biology-inspired Computing

Many biological systems can be viewed as being composed of interacting elements that exchange and process information. In this context, these systems may provide a rich source of computational models and problem solving methods for CICT's Automated Reasoning, Human-Centered Computing, and Intelligent Data Understanding program elements. For example, many of the autonomy problems faced by NASA have already been solved by biological systems. The common housefly, for instance can, on many dimensions, outperform our most advanced autonomous systems. The basic idea motivating this endeavor is to learn how biological systems address the apparent complexity of autonomous activities and then exploit that knowledge to develop advanced computational systems. Current efforts in neural networks, genetic algorithms, cognitive science, and gene sequencing may lead to biologically inspired approaches to storing information and performing computations.

Effective autonomous agents must be able to simultaneously perform multiple levels of action. From low-level reflexive actions, such as keeping a person in a desired position based on gravitational forces, to high-level cognitive actions, such as planning to satisfy mission goals, the autonomous agent must somehow integrate the action demands from these various levels. Through efforts to understand how organisms perceive, react, and reason, one can begin to organize the complexity involved in developing autonomous agents and in understanding the optimal approaches for both human centered computing and autonomous agents.

Neural computing research has led to approaches to learning, adaptation, and control that may result in significant advances in our understanding about how to solve related problems. Much of the current work in neural computing deals with recognition of instantaneous patterns (e.g. face recognition in a static image). Biological systems, however, exist in environments rich with temporal information. The autonomous systems envisioned in this program will need to take advantage of this additional information. Thus, understanding recurrent network architectures that store, process, and retrieve temporal information will be a central research issue in the years to come.

- The specific goal is to develop biologically inspired computing models and demonstrate them on a NASA relevant problem.

### 5.6.3 Molecular Computing

As we learn how genetic information is encoded, stored, retrieved - particularly if new levels of information primitives are discovered - new models of computation may result. One example of the class of models that could ensue is the "DNA based Computer."

Biologically inspired computing uses molecules with their appropriate chemical and/or physical operations for massively parallel computing. In this case, each molecule serves as a processor or a Turing machine. Molecular computing, using DNA, was first demonstrated in a traveling salesman problem - presented in a seminal work by Adleman in 1994 (Science, 266, 1021, 1994). Molecular computers, however, are still in the conceptual stage, and few of many proposed computing models and algorithms have been tested because the required lab operations are slow, expensive and complicated.

A molecular computer is comprised of specially selected molecules. In some cases such as DNA based computing, a combination of these molecules will result in the solution to some problem. In other cases, one utilizes the switching properties of the molecule to direct or block the transfer on electrons. In recent years, we have seen couple different concepts based upon the switching properties. However, none of the proposed approaches incorporate defect and fault tolerance. Biocomputing systems are well known for their self-healing and self-repair. Therefore, more work is needed to advance molecular computing. This approach, like Quantum Computing, might revolutionize our approach to computing.

- The specific goal is to develop adaptable architecture for molecular computing and demonstrate using simulation.

## 5.7 Bio-Nanotechnology (BN)

Bio-Nanotechnology (BN) is a sub-project under ITSR. Nanotechnology is the science of creating functional materials, devices, and systems through control of matter on the nanometer (atomic) scale and the exploitation of novel phenomena and properties (physical, chemical, and biological) at that length scale. Control of organization at the atomic level provides the opportunity to create function-specific materials at the micro and macro scales. It is important to emphasize that nanotechnology is not simply another step toward 'top-down' miniaturization. It represents a fundamental change in approach - particularly self assembly and other 'bottom-up' approaches - that exploits new behaviors dominated by quantum mechanics, material confinement, and large interfaces.

Within the next decade or two, nanotechnology is expected to have profound impact on all the NASA Enterprises by enabling: revolutionary, lighter, smaller spacecraft (micro, nanospacecraft); powerful, small, low power consuming computers; radiation-hardened electronics; nano-electronics; biosensors for astrobiology and astronaut health monitoring; biomedical sensors and in-vivo medical devices; artificial neural systems; robotics; novel nanoelectromechanical systems (NEMS); and advanced materials for solar sails, satellite tethers and space launch vehicle structures. The bio-nanotechnology task will focus the research and development effort on aspects of the Agency's interests by leveraging government and university research, and by transferring maturing technologies to NASA missions as well as to industry and other government agencies.

### 5.7.1 Nanomaterials for Electronics and Sensors

This task will develop new materials from the atomic level up and characterizing the electronic, chemical, and mechanical properties for the development of nanoelectronics, nanosensors, nanoinstruments, and nanostructures "by design". Research and development in this area is focused on the development and characterization of carbon nanotubes, inorganic nanowires, quantum dots, protein nanotubes, engineered molecules for nanoelectronics applications, and synthetic nanopores. The specific objectives are as follows:

- Nanoporous media suitable for application studies
- Analysis of molecular transport in and around carbon nanotubes to evaluate feasibility to build structures, sensors and materials for specific applications
- Identification of materials and molecules having suitable properties to enable the development of sensors, electronics, and instruments and to identify property changes that would improve performance of the sensors and electronics
- Proof of concept development of a membrane systems based on single-walled carbon nanotubes as a catalyst/catalyst support for toxic gas conversion
- Study of the effects of the space radiation environment on emerging nanotechnology based electronics and sensors

### 5.7.2 Modeling and Analysis of Nanotechnology

This task will further the fundamental understanding of the novel physics and chemistry involved in materials and structures at the nanoscale and to provide both insight and data to developing models in these areas. This task also encompasses the development of computational tools for multidimensional, multiscale simulations.

Extensive investigations using computational simulations on the electrical, chemical, mechanical, optical and thermoelectric properties of the nanobuilding blocks will provide a vehicle to understand how these nanostructures and devices function, as well as how to design useful devices at the nanoscale. The specific objectives are as follows:

- Simulate structure, nanomechanics, and chemistry of single- and multi-wall carbon nanotubes and carbon nanotube-polymer composites
- Study the effects of many-body Coulomb interactions of optical properties of intersubband transitions of semiconductor nanostructures
- Explain experiment observations and give predictions and guidance for experiments
- Design new nanodevices based on carbon nanotube (CNT) and polymer systems

- Understand the thermal, electronic, and mechanical properties of CNT-polymer composites and nanosystems composed of polymer molecules and carbon nanotubes
- Develop computational methods and software to study the structure and properties of nanowires; predict and explain experimental observations on nanowires
- Model interaction of organics such as benzene and toxic gases with carbon nanotubes and identify ways to improve selectivity and sensitivity
- Compute electrical conductivity, ionization potentials, electron affinities, and phonon properties for DNA; study adsorption of O2 on DNA and the effect on conductivity
- Model chaperonin proteins used as the building blocks in bio-nanotechnology

### 5.7.3 Manufacturing at the Nanoscale

The objective of this group is to develop tools, methods, and processes suitable for the manufacturing of nanostructures, nanoelectronics and nanodevices that will enable new technologies for NASA Enterprises to use in pursuit of their goals and missions. The objectives for this task are the following:

- Develop micro- and nano-fabrication processes that will produce nano-chemical sensor and bio-sensor devices at wafer scale
- Study and optimize the chemistry of RF Plasma Enhanced, DC Plasma/Hot Filament, and Thermal Chemical Vapor Deposition for growth of nano materials
- Develop and validate multidimensional plasma materials processing reactor models for growth of nano building blocks
- Purification methods for carbon nanotubes
- Expand the use of genetic engineering for the ordered deposition or in situ formation of array of inorganic nanoparticles
- Characterize crystalline protein template arrays for use in the development of logic, memory, and/or sensing-based devices.
- Scanning probe nanolithography with carbon nanotube probes
- Development and characterization of quantum dots for sensor and instrument applications

### 5.7.4 Nanoelectronics

The nanoelectronic task develops discrete nanoelectronic components and devices taking advantage of the novel quantum effects manifested at the nanoscale. Specific objectives included in this task are as follows:

- Develop novel device architecture and integration
- Develop computer codes to characterize the inter- and intra-molecular interactions of conducting molecules and electrode contacts
- Design improved molecular memories and molecular switches and integration into devices
- Design and synthesize novel electroactive molecules which possess desirable and novel physics for use as active electronic components
- Develop theory and simulation tools to model charge transport in semiconducting and molecular nanoelectronics devices and structures

- Develop atomic-scale devices which can replace the present silicon transistors without changing the circuitry
- Design and analyze biomimetic dentritic devices and architectures based on branched carbon nanotube junctions and networks

### 5.7.5 Bio-Nano-based Diagnostic Tools

This functional area will provide novel diagnostic tools developed from fusion of biology and nanotechnology that enable missions and science investigations of particular interest to NASA enterprises. Specific objectives are as follows:

- Develop ultrasensitive biosensing platform based upon carbon nanotube array for the detection of biomolecules, nucleic acids, antigens, and pathogens or toxins
- Develop water and NO bio-inspired sensor based on bioinorganic model complexes and vertically aligned carbon nanotube array platform
- Nanopore-based DNA sequence identification
- High-resolution imaging of biological samples in aqueous environments using atomic force microscope carbon nanotube tips

### 5.7.6 Nano-based Sensors and Instruments

This functional area will exploit nanoscale phenomena to develop sensors and instruments providing sensing and function that could otherwise not exist without nanotechnology. The specific objectives are as follows:

- Develop and characterize chemical sensor platforms
- Develop nano-based sensors for chemical analyses that cannot be developed for space applications with conventional technologies
- Study optical properties, coupling, and interaction as well as optical confined modes in a nanolaser Electron sources for a variety of instruments
- Nano-based Infrared Detectors
- Quantum Microcalorimeters

### 5.7.7 Nanocomputing

The nanocomputing task is pursuing device and system architectures that will enable nanocomputing. The specific objectives are as follows:

- Develop a new class of algorithms for combinatorial optimization problems based on ideas from quantum mechanics and collective phenomena in complex systems and apply to the problem of automated design of nanoelectronic architectures
- Investigate evolutionary and other bio-inspired algorithms for novel nanotechnology computing architectures
- Study endo-fullerenes and doped diamond nanocrystals for solid state quantum computers
- Study the possibility of optical information transmission and processing using periodic quantum dot lattice

# 6.0 SCHEDULE

Figure 6-1 shows the ITSR schedule of Project level milestones, FY02 through FY06, due dates, and progress to date.

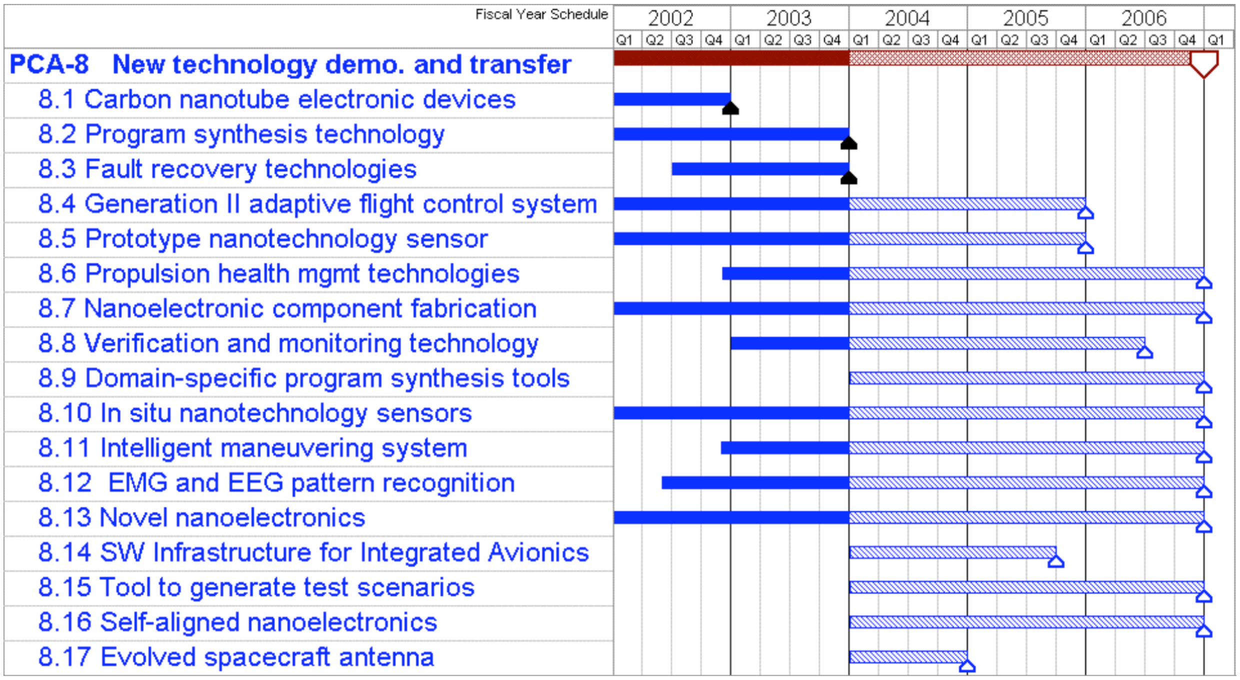


**Figure 6-1 Project level milestones (abbreviated) and due dates**

# 7.0 ACQUISITION STRATEGY AND PERFORMING ORGANIZATIONS

The ITSR Project coordinates with other NASA Aerospace Technology Enterprise program activities and with other CICT program activities. ITSR provides interim results of value to the aerospace community by developing, in close cooperation with NASA programs and the national aerospace community, near-term, intermediate, and long-term milestones that at each stage provide "end-user" benefits.

Work on the ITSR Project is performed at Dryden Flight Research; Ames, Langley, Glenn and Marshall Space Flight Centers; and the Jet Propulsion Laboratory (JPL) by civil servants and contractors. Some work is also performed off-site by contractors. Other work is performed at universities under grants, cooperative agreements, and, sometimes, contracts.

Due to the broad nature of ITSR, a variety of acquisition instruments will be employed. Procurements will be in accordance with approved procedures at the procuring Centers. Free and open competitive procurements will be used to the maximum extent possible. Among the approaches to procurement, the most likely include NASA Research Announcements (NRA), NASA Cooperative Agreement Notices (CAN), and Requests for Proposal (RFP). These vehicles will result in grants, cooperative agreements and contracts. For any onsite contractors, performance-based contracts are the preferred instrument.

# 8.0 AGREEMENTS

Though not intended to be all-inclusive, the following list of agreements is representative of the type of agreements and collaboration entered into for support of ITSR research. Agreements are detailed in sub-project plans.

*Internal Agreements:*

1. ITSR/ASET—Ames and Langley agreements with Honeywell for collaboration on DEOS.
2. ITSR/ASET—Ames agreement with JPL MDS on V&V collaboration.
3. ITSR/ICD—Memorandum of Agreement (MOA) between NASA Ames and NASA Dryden: "F-15 and C-17 Intelligent Flight Control Experiments/Letter of Intent" (December 15, 2000).
4. ITSR/ICD—Memorandum of Agreement (MOA), DFRC-190, between NASA Dryden and the C-17 SPO: "Use of a C-17 Aircraft to Support NASA Flight Research Programs" (May 20, 1999).
5. ITSR/BN—Agreement with Code U for chemical sensor work from an award from their NRA.

*External Agreements:*

1. ITSR/ASET—Ames agreement with Kansas State University for use of Bandera front-end for software model checking.
2. ITSR/ASET—Ames agreement with approximately a dozen universities for collaborative research on Java Pathfinder (JPF).
3. ITSR/ASET—Ames agreement with University of Wyoming for program synthesis collaboration (currently in form of IPA with chair of department).
4. ITSR/ASET—Langley agreement with Rockwell Collins for Formal Methods work.
5. ITSR/ICD—Contract with General Electric Aircraft Engines for a one-year study to explore all potential schemes to extend engine life.
6. ITSR/ICD—Phase II STTR Contract for Onboard and Remote Vehicle Health Management.
7. ITSR/ICD—Phase II STTR Contract for Intelligent Control for Autonomous Remote Spacecraft.
8. ITSR/ICD—Reimbursable Space Act Agreement Between NASA Ames Research Center and Quantum Applied Science and Research Inc. for Evaluation of Capacitive Electrodes for Electrodes for Neuroelectric Readout and Their Derivative Applications.
9. ITSR/BN—Grant from FAA.
10. ITSR/BN—Grant from DARPA.
11. ITSR/ASET—Ames/NSF MOU between NSF and NASA on Research in High Dependability Computing November 2001.
12. CICT/ITSR and ECS and Flight Research Program: Intelligent Flight Control Technology Development Agreement (under development).

# 9.0 RISK MITIGATION OVERVIEW

The ITSR Project Office will assess risk mitigation or elimination approach on an ongoing basis. The following are general considerations appropriate to a technology development type of program.

*Risk Management Process:*
Each sub-project manager will identify the principal technical risks and document those in the applicable sub-project plans. These will then be addressed in an overall risk reduction approach.

*Risk Management Plan Content:*
The risk management plan is incorporated as a section of the individual sub-project plans. The content includes a statement of the risks, a description of any mitigation steps, and a statement of the recommended review and approval entities.

*Primary Risk Drivers:*
The primary risk drivers for technology development programs are (1) critical enabling technologies encountering unexpected developmental difficulties and (2) resources unavailable because of competing technology development programs.

The ITSR Project Office will follow the Continuous Risk Management (CRM) process with the goal of reducing to an acceptable level the impact of issues and uncertainties on the Project. Individual risks will be tracked at the sub-project level. The Project Office will define common risk definitions for the sub-projects to use. The sub-projects will provide to the Project Office regular status of their high and medium risks as described below. The Project Office will separately track the Project Office unique risks. Formal risk management tracking will be realized through the updates of the Project and Sub-Project Plans, together with the approval process for those plans.

As the Project Office and the Sub-Project Managers review progress toward goals along with an assessment of risks, additional risks may be discovered through project and sub-project measurements. Additionally, some related risks from different sub-projects might be combined into a common risk.

The following table shows risks identified at the Project level:

| Top Risks | | G Overall G Cost G Schedule G Technical | **Probability** | **Impact** | **Mitigation Plan** |
|---|---|---|---|---|---|
| | | **Mitigation:** | | | |
| G | 1. Funding reduction | Portfolio reduction | Moderate | High | Accept Risk |
| G | 3. Technical Capability Delivered | Multiple technologies under development | Moderate | Moderate | In Place |
| G | 2. Schedule Risk | Resource trades among prioritized products | Low | Moderate | Under Development |

# 10.0 INDEPENDENT REVIEWS

ITSR is subject to a number of scheduled periodic and non-periodic reviews, to ensure research quality and appropriate programmatic action. These reviews may be held at the Center level, the Program level, NASA Headquarters level, or other level. The table below shows the top-level reviews for the ITSR Project.

| Type of Review | Last Review | Next Review | Purpose |
|---|---|---|---|
| NRC (ASEB) | Apr-03 | Jun-05 | Technical |
| IIR (IPAO) | None | Nov-03 | Programmatic |
| ATAC-MSM | May-03 | Nov-03 | Programmatic |

# 11.0 BUDGET

| IT Strategic Research<br>Full Cost Budget by Subproject | FY2004 | FY2005 | FY2006 | FY2007 | FY2008 | FY2009 |
|---|---|---|---|---|---|---|
| **Budget Authority (PY $ in Millions)** | **54.7** | **43.2** | **48.5** | **0.0** | **0.0** | **0.0** |
| Intelligent Controls and Diagnostics | 8.9 | 0.4 | | | | |
| NeuroElectric Machine Control | 1.7 | 3.9 | 7.2 | | | |
| Automated Software Engineering Technologies | 3.8 | 5.3 | 5.3 | | | |
| Bio-Nanotechnology | 24.1 | 19.2 | 22.3 | | | |
| Evolvable Systems | 4.7 | 4.5 | 4.9 | | | |
| Revolutionary Computing Algorithms | 4.1 | 3.0 | 2.0 | | | |
| URETI-Nanocomputing Electronics | 3.2 | 3.2 | 3.1 | | | |
| HQ Interdisciplinary | 4.2 | 3.7 | 3.5 | | | |

| IT Strategic Research<br>Full Cost Budget by Center | FY2004 | FY2005 | FY2006 | FY2007 | FY2008 | FY2009 |
|---|---|---|---|---|---|---|
| **Budget Authority (PY $ in Millions)** | **54.7** | **43.2** | **48.5** | **0.0** | **0.0** | **0.0** |
| ARC | 39.9 | 31.5 | 36.5 | | | |
| GRC | 1.7 | 0.4 | 1.0 | | | |
| JPL | 2.0 | 1.8 | 1.8 | | | |
| LARC | 6.9 | 5.7 | 5.7 | | | |
| HQ | 4.2 | 3.7 | 3.5 | | | |

## 12.0 CUSTOMER ADVOCACY & DEFINITION

Customers are principals within selected segments of the U.S. aeronautics manufacturing industry, selected DoD organizations, and other U.S. Government Agencies. A listing of ITSR customers by technology area is shown below.

| **Project/Sub-Project** | **Principal NASA Customers** |
|---|---|
| Information Technology Strategic Research (ITSR) Project | Programs, Projects, and Missions within NASA's Aerospace Technology, Earth Science, Space Science, Biological and Physical Research, and Human Exploration and Development of Space Enterprises. |
| Bio-Nanotechnology (BN) Sub-Project | Space Science Enterprise (Code S); Biological and Physical Research Enterprise (Code U); Aerospace Technology Enterprise (Code R) |
| Evolvable Systems (ES) Sub-Project | Space Sciences Enterprise; Aerospace Technology Enterprise |
| Automated Software Engineering Technologies (ASET) Sub-Project | Aerospace Technologies Enterprise; Space Science Enterprise |
| Intelligent Controls and Diagnostics (ICD) Sub-Project | Earth Sciences Enterprise (Sub-orbital Science Program); Space Sciences Enterprise; Aviation Safety Program; Space Launch Initiative, UEET Program. |
| Revolutionary Computing Algorithms (RCA) Sub-Project | Space Science Enterprise, Aerospace Technology Enterprise, Earth Sciences Enterprise |

The process to ensure customer advocacy is tailored to each specific set of customers and users of the research and technology products and services. Workshops and formal/informal communications are used to attract a larger audience of prospective customers, and their opinions concerning technology needs are regularly solicited. Candidate future program activities will be brought to sub-project and project management for review, evaluation and disposition. More significant program possibilities will be taken to CICT program management for consideration and disposition.

Within the CICT Program, points of contact have been established as Enterprise Liaisons. These contacts maintain regular communication with the Enterprise Technology Executive Board (TEB) and other key Enterprise representatives. The ITSR Project interfaces with these Enterprise Liaisons to understand and update requirements, recommend and evaluate technology directions and identify opportunities for collaboration toward the goal of technology infusion.

# 13.0 CONTROLS

Progress toward goals is measured using a combination of project management techniques. These include milestone measurement, maintenance of a change log as well as updates to this plan, and reviews. Internal reviews of the project are listed in the PROJECT MANAGEMENT OVERVIEW Section, and external reviews are listed in the INDEPENDENT REVIEWS Section of this Project Plan.

*Milestones:*

Progress against milestones at the sub-project level is evaluated by the individual Sub-Project Manager. Progress against project and sub-project milestones is monitored at both the Project Office level and the Program Office level. Project and sub-project reports are provided to the Program Office on a monthly basis, and milestone status information is updated in NASA's Erasmus database on a monthly and quarterly basis. Reports on completion or non-completion of program level milestones, as well as significant project-level progress, are provided to the Enterprise on a quarterly basis.

*NASA Reviews:*

The individual goals of the sub-projects, as well as the research activities aimed at reaching those goals, are reviewed throughout the year through informal and formal reviews. The CICT Program Office prepares a budget plan and submits that plan to the Enterprise for approval in June of each year. As a result of the budget meetings in June, and in response to any Decision Packages that are provided as output of the meetings, the ITSR Project makes appropriate adjustments to the research activities taking place within the Project. Changes to milestones or resources are tracked in a Change Log, which is maintained in an appendix of this Project Plan. At the change of the fiscal year, the accumulated changes in the Change Log are evaluated, and, if prudent, the Project Plan is updated.

The work being performed in the ITSR Project is reviewed semi-annually (nominally) by the Lead Center Program Management Committee (PMC). Mid-year changes to the ITSR Project plan may be addressed at the Lead Center PMC review when appropriate.

*Change Control:*

Proposed changes to Project level (and below) milestones that do not affect Program level milestones are considered and approved by the ITSR Project Office. Changes affecting Program level milestones are brought forward to the CICT Program Office for approval. Changes to Project-level milestones are tracked in a Change Log, which is maintained as an appendix to this Project Plan until the changes can be accommodated in an updated Project Plan.

Proposed sub-project level changes are sent to the ITSR Project Office by the responsible Sub-Project Manager via e-mail. Following receipt of the e-mail, a meeting is set up among the ITSR

Project Office (Manager and/or Deputy Manager, Financial Executive), the Sub-Project Manager, and any other managers affected by the change. If the proposed changes are nominally approved by the Project Office and affect this Project Plan or program/project level milestones, they are carried forward to the CICT Program Office as outlined in the previous paragraph. The outcome and changes of that meeting are then transmitted to affected parties (CICT Program Office, line management of performing organizations, etc.), and plans are updated accordingly.

# 14.0 RELATIONSHIPS TO OTHER PROGRAMS AND/OR PROJECTS

Work on the ITSR Project is performed at Dryden Flight Research; Ames, Langley, Glenn and Marshall Space Flight Centers; and the Jet Propulsion Laboratory (JPL) by civil servants and contractors. Some work is also performed off-site by contractors. Other work is performed at universities under grants, cooperative agreements, and, sometimes, contracts.

Every effort is made to minimize, reduce, or otherwise eliminate dependencies on other Programs for products produced within ITSR. There are currently two dependencies in the ITSR Project:

> The F-15 flight vehicle is funded by the Vehicle Systems Program within the Code R Enterprise. Flight test for the FY05 milestone is governed by the Memorandum of Intent referenced in Section 8.0 (Agreements).
>
> Resources associated with the New Millennium Program are being used to provide flight-readiness assessment of the evolved antenna designed in ITSR.

Specific activities, both internal and external to NASA, will be detailed in sub-project plans.

# 15.0 TECHNOLOGY ASSESSMENT

ITSR is an information technology research project that explores new and evolving technologies for suitability for further research and eventual infusion into NASA missions. ITSR conducts TRL 2 - 6 research activities intended to prove feasibility, and to develop and demonstrate information technologies for eventual introduction into NASA missions. Long-range missions in the various NASA Enterprises are used as drivers of ITSR's information technology research, providing the requirements context for the research activities.

# 16.0 COMMERCIALIZATION OPPORTUNITIES AND TECHNOLOGY TRANSFER

An objective of ITSR is to ensure rapid and effective dissemination of the research results and technology to U.S. industry, the U.S. aviation operators and other government agencies. Advancements in each project area will be advanced to a TRL between 3 and 6. Beyond TRL 6, the activity will be transferred to industry or other government agencies via a number of technology transfer mechanisms. Technology transfer mechanisms and commercialization opportunities depend on the maturity of the program products.

A variety of transfer mechanisms will be employed. The most important is through direct involvement of the users in the Project described in this plan through participation in project formulation, cooperative or joint program conduct, and direct contract of R&D. ITSR Project resources will fund R&D contracts and grants which ensure direct transfer of technology, increasing the likelihood of direct and speedy inclusion in products. Exchange will also occur among the participants through special technical working group meetings conducted at the project level. Other methods of transfer include publication of technical reports, personnel exchanges between NASA, industry and other government agencies via memoranda of agreement (MOAs), and technical demonstrations at NASA and user facilities.

The ITSR Project will work closely with the Technology Commercialization Office at the respective centers to help communicate technology commercialization opportunities to a wide range of potential users outside the traditional aerospace community. This includes such fields as medical, ground transportation, communications, and K-12 education.

# 17.0 DATA MANAGEMENT

Data generated by the ITSR Project is generally not of a classified or sensitive nature. Sensitive and proprietary data will be handled in accordance with IT security guidelines NPG 2810.1 Security of Information Technology.

# 18.0 LOGISTICS

The ITSR Project is a research and technology development project. Technology products are typically transferred at TRL 4 to 6 to a receiving project, program, or mission. In the event a technology is directly infused into a mission, the specific logistics requirements of the receiving mission will be applied.

## 19.0 TEST AND VERIFICATION

Architectures and software will be evaluated using performance benchmarks based on real applications in the areas of aerospace transportation systems, and Earth and space sciences. Research software verification will be through comparison with current practice or state of the art. Technologies for mission infusion will be subject to stricter verification and validation standards as mandated by the receiving mission.

## Appendix A:  Glossary

| | |
|---|---|
| APMC | ARC Program Management Council |
| ARC | Ames Research Center |
| ARO | Army Research Office |
| ASET | Automated Software Engineering Technologies |
| ATAC | Aerospace Technology Advisory Committee |
| BN | Bio-Nanotechnology |
| CAN | Cooperative Agreement Notice |
| CICT | Computing, Information, and Communications Technologies |
| CNIS | Computing, Networking and Information Systems Project |
| CNT | Carbon Nanotube |
| CRM | Continuous Risk Management |
| DARPA | Defense Advanced Research Projects Agency |
| DESS | Distributed and Embedded Sensors |
| DF | Data Fusion |
| DNA | Deoxyribonucleic acid |
| DoD | Department of Defense |
| EB | Executive Board |
| ECS | Engineering for Complex Systems |
| EEG | Electroencephalogram |
| EMG | Electromyogram |
| ES | Evolvable Systems |
| FAA | Federal Aviation Administration |
| FTE | Full Time Equivalent |
| FY | Fiscal Year |
| GPRA | Government Performance Results Act |
| HJB | Hamilton-Jacobi Bellman |
| HTE | High Temperature Electronics |
| HW | HealthWatch |
| ICD | Intelligent Controls and Diagnostics |
| ICHM | Integrated Control and Health Monitoring |
| IFC | Intelligent Flight Control |
| IHASM | Intelligent Health and Safety Monitoring |
| ILEC | Intelligent Life Extending Control |
| IS | Intelligent Systems Project |
| IT | Information Technology |
| ITSR | Information Technology Strategic Research |
| JPL | Jet Propulsion Laboratory |
| JSC | Johnson Space Center |
| MOA | Memorandum of Agreement |
| MSM | Mission and Science Measurement Technology |
| MWLS | MEMS White Light Source |
| NASA | National Aeronautics and Space Administration |

| | |
|---|---|
| NCI | National Cancer Institute |
| NeMC | NeuroElectric Machine Control |
| NEMS | Nanoelectromechanical systems |
| NPG | NASA Procedures and Guidelines |
| NRA | NASA Research Announcement |
| NRC | National Research Council |
| NSA | National Security Agency |
| OAT | Office of Aerospace Technology |
| PCA | Program Commitment Authority |
| PCHM | Propulsion Control and Health Monitoring |
| PDR | Preliminary Design Review |
| PMAS | Program Management Accomplishment System |
| PMC | Program Management Committee |
| PSS | Photonic Sensors and Systems |
| R&T | Research and Technology |
| RCA | Revolutionary Computing Algorithms |
| RFP | Request for Proposal |
| RTD | Resonant Tunneling Diode |
| SC | Space Communications Project |
| TEB | Technology Executive Board |
| TIDB | Technology Inventory Database |
| TRL | Technology Readiness Level |
| TRR | Technology Readiness Review |
| UEET | Ultra-Efficient Engine Technology Program |
| UPN | Uniform Program Number |
| URETI | University Research Engineering and Technology Institute |
| WBS | Work Breakdown Structure |

# Appendix B: Change Log

When Project reviews, reports, or system analyses identify that it is prudent to make changes to the funding, workforce-loading, milestones, or research descriptions of this Project Plan, they are kept in a Change Log. The table below contains a log of changes to the Project Plan. The log will be supplemented as necessary by records from the change control system in effect at the time of the proposed change.

| Date | Content | Changes |
|---|---|---|
| June 2002 | ITSR Project Plan | Narrative Plan FY02. |
| September 2002 | ITSR IBPD FY03 | IBPD Plan FY03. |
| July 2003 | ITSR IBPD FY04 | IBPD Plan Update FY04 |
| September 2003 | ITSR Project Plan FY04 | Narrative Plan Update FY03. |